AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 105:407–417 (1998)

Demographic and Socioeconomic Determinants of Variation in Food and Nutrient Intake in an Andean Community

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KEY WORDS interindividual and intraindividual variation; food; nutrients; diet; SES; Ecuador

ABSTRACT Understanding the sources of variation in a community's diet is vital for development work, as well as being a source of anthropological and cultural insights. Previous surveys in the South American Andes suggest that nutrient deficiencies may be widespread; however, such interpretations have remained tentative since variance in Andean populations' diet has not been thoroughly examined. In this paper we consider the variation in diet due to variation in age, sex, and socioeconomic status and variation attributed to inter- and intraindividual variation in the diet.

One to six days of dietary data (mean = 3.1) were collected via 24 h recalls from 221 residents of a small, rural community in highland Ecuador. The contribution of various food groups to the diet varied with land holdings and age but not sex. For example, animal-derived foods contribute more and tubers contribute less to the diet of the households with ≥5 Ha, and sweets contribute more to the diet of children.

The interindividual variation in energy and nutrient intake was low and the intraindividual variation high relative to developed countries. The consequence are twofold. First, because interindividual variability is low, group mean intake can be estimated relatively easily, facilitating group comparisons. Second, because intraindividual variation is high, individual nutrient intake cannot be easily estimated, which will decrease the ability to detect associations between nutrient intake and health measures. This knowledge of the sources of dietary variation can lead to better study and survey designs in the rural Andes and elsewhere in the developing world. Am J Phys Anthropol 105:407–417, 1998.

A considerable body of literature has examined the diet of rural Andean populations (e.g., de Meer, 1993; DeWalt et al., 1992; Leonard, 1987; Leonard et al., 1993; Ferroni, 1982; Picón-Reátegui, 1976; Weismantel, 1988). This literature has described in detail the foods consumed and distribution patterns of the food and offers some consideration of protein and energy intakes and adequacy. Vitamins and minerals have been given less attention. This gap is problematic, given that there is ample evidence that micronutrient deficiencies as well as protein and energy malnutrition are important in shaping growth and health status in the developing world (Allen, 1994). It is thus useful to study the sources of vitamins and minerals in the Andean diet so that nutrient-rich and nutrient-poor foods and food groups

Contract grant sponsor: Natural Science and Engineering Council, contract grant number OGP-0116785; Contract grant sponsor: US National Science Foundation, contract grant number SBR-9106378.

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Received 29 July 1996; accepted 16 November 1997.

are identified and food-based approaches for addressing nutrient deficiencies may be developed. It is also important to study the variation in vitamin and mineral intake, because knowledge of sex-, age-, and wealth-based variation is required for development work and knowledge of inter- and intraindividual variation in the diet is important for research into the relationship between diet and health. When 2 or more days of data are available per subject, an ANOVA may be used to partition the source of variance to inter- and intraindividual variation (Beaton et al., 1979). This enables the researcher to calculate the accuracy of dietary intake estimates and the attenuation factor of nutrient-health correlations, (i.e., the amount by which observed correlations between nutrient intake and health measures will be less than the unobserved "true" correlation [Anderson, 1986]). Thus, in this paper, the dietary sources of vitamins and minerals, the variation in diet with age, sex and relative wealth, and the inter- and intraindividual variation in nutrient intake are considered in a community in rural highland Ecuador.

MATERIALS AND METHODS

Study population

At the time these data were collected (January–June, 1994) there were approximately 500 residents in 95 households in the study community; all are Spanish-speaking Mestizos (mixed native and Spanish ancestry). The community lies close to the equator (1°2′ S) in highland Ecuador between 3,300 and 3,600 m above sea level, 18 km outside of the town of Salcedo, 110 km south of the capital city, Quito. They are farmers, growing mostly potatoes, barley, and fava beans and raising dairy cattle for personal consumption and sale. The community has a chlorinated water system (although the quality of the water is often poor), and there is electricity in every home. Approximately half the homes have a latrine.

Crops are sown and harvested throughout the year, and seasonal fluctuations in agricultural productivity are not apparent. Consequently, there are no measurable season-based variations in nutrient intake (Berti, 1996).

TABLE 1. Age-sex composition of study sample

Age (years)	Males	Females	Total
1.5–4.9	17	13	30
5.0–9.9	22	15	37
10.0–14.9	18	12	30
15.0–19.9	13	8 + 2L[1]	23
20.0–29.9	21	14 + 2P,4L	41
30.0–39.9	9	8 + 2L	19
40.0–49.9	10	11 + 1L	22
>50.0	10	9	19
Total	120	101	221

[1] Women are nonpregnant, nonlactating unless indicated as P (pregnant) or L (lactating).

A formal randomization procedure for subject recruitment was not used. Rather, residents—approximately evenly distributed throughout the geographic and socioeconomic range of the community—were approached and asked to participate. In total, 221 of the residents from 50 households were recruited. Thirty-eight individuals provided 1 day of dietary data, 16 provided 2 days, 64 provided 3 days, 86 provided 4 days, 15 provided 5 days, and two provided 6 days. There were only two refusals to participate (for unspecified reasons) and no instances of subjects explicitly dropping out after recruitment. Repeat interviews were not done if the subjects could not be relocated or if the study period ended before an appointment could be made, thus resulting in the uneven number of days of data per subject. There were no differences in diet, age, or land holdings between subjects who provided different numbers of days of data. The age-sex composition of the study sample is shown in Table 1. Breast-fed infants were excluded from the study, and the youngest participant was approximately 1.5 years.

Adult subjects were paid 2,500 sucres, and subadult subjects were paid 1,000 sucres per interview. At the time of the study, 2,500 sucres were equivalent to approximately US $1.20. An adult labourer would earn between 5,000 and 10,000 sucres for 1 day's work. The Human Ethics Committee of the University of Guelph approved this study.

Data collection methods

A quantitative 24 h recall of the previous day's diet was used to collect dietary data (Gibson, 1990). Consistent with good prac-

tice (Gibson, 1990) to increase the accuracy of the recalls, representative samples of local foods were weighed to the nearest gram, and the volume of all bowls and cups in which each individual's meals were served was measured to the nearest 5 ml. In the community, family members were usually served the same food (typically soup, rice, or potatoes) and drink (usually milk- or water-based coffee, at times herbal teas) from a common pot. We calculated the total volume in the pot and the proportion served to each subject. Homogeneity of contents was assumed (consistent with our extensive informal observations) unless otherwise indicated.

Each subject was questioned for the quantity of food (number of bowls or cups) consumed, but the cook was asked for the ingredients of common-pot foods. In practice, much of the interviewing proceeded as a consensus recall, with the husband and children helping the mother with the ingredients of the common pot and all family members helping one another, particularly children, with the amounts consumed, while both the first author and one field assistant prompted and recorded. The consensus recall method has been shown to improve dietary recall accuracy (Eck et al., 1989). If a member of the household was not present at the time of the dietary recall but did spend all of the previous day with the family, and they knew what the missing member ate (i.e., usually the same as themselves), then their reports of the missing member's intake were used. All subjects were carefully probed for other foods eaten outside the home.

Ecuadorian (and occasionally Latin American) food composition tables (Ministerio de Salud Pública del Ecuador, 1988; Woot-Tsuen and Flores, 1961) were used in the calculation of intake of energy, protein, calcium, iron, vitamin A, thiamin, riboflavin, niacin, and vitamin C from most foods. For the few foods not available in these tables and for calculating the intakes of zinc, vitamin B-12, and folate, values were imputed from Canadian food tables (Dubuc and Lahaie, 1994). Using cross-border food composition tables may be problematic (Bressani, 1992), but, if the error in composition estimates are random, not biased, the likely effect on estimated intake is minimal (Beaton, 1987) (although when the diet is analyzed in small groups of foods, as in this paper, it is increasingly likely that random errors in the composition tables influence the estimates of intakes).

Furthermore, the quality of the Ecuadorian tables is at times uncertain, for often neither the analytical methods nor food preparation (e.g., raw, boiled, peeled) are described, and some estimates of composition are based on very few samples (e.g., one or two), and the extent of intra- and inter-country variability in food composition is unknown. This is, unfortunately, usually the case in studies in developing countries. Composition estimates of foods that were in any two of the Ecuadorian, Latin American, and Canadian food tables were compared, and, while differences existed, there were no cases where the differences were so great that any one was in obvious error, with the possible (and important) exception of iron concentration in potatoes. The Ecuadorian tables report 2.6 mg, the Latin American tables, 0.8 mg, Bolivian tables 1.0–1.5 mg (varietal differences) (Ministerio de Previsión Social y Salud Pública, 1979), and the Canadian tables 0.31 mg iron per 100 g wet weight. A composite value of 1.6 mg was used. Given the importance of potatoes in the diet of the community and the importance of potatoes as a source of iron (~40% of total), an error in estimating their iron content will substantially influence estimates of overall iron intake and variation in iron intake.[1]

Water samples from the community were brought back to Canada and analyzed (by Guelph Chemical Laboratories) for iron and calcium content using Inductively Coupled Plasma (APHA/AWWA/WPCF, 1990).

The amount of land owned by each household, measured in hectares (Ha) (self-reported and verified with key informants) was used as a proxy measure of socioeconomic status (SES). The amount of land a household owned was correlated with other indicators of SES—number of large animals

[1]However, even if the iron content of potatoes was 0.31 mg/100 g, iron intakes would still be high, and iron deficiency anemia resulting from inadequate dietary iron would still only be ~1% (Berti, 1996).

TABLE 2. Food group composition (foods that are italicized are local foods with no English equivalent)

Animal	Tubers	Grains	Fruits and vegetables		Oil	Sweets	Spices	Water	Other
Beef	*Melloco*	Barley	Apple	Mango	Lard (vegetable, pork, margarine)	*Bolos*	*Achiote*	Water	Beer
Chicken	Cassava	Bread	Avocado	*Naranjilla*	Vegetable oil	Chocolate powder	*Ajinomoto*		Candy
Cheese	Oca	Corn	Banana (green, yellow)	Onion (white, red)		Cola	*Apio*		Cookie
Eggs	Potato	Crackers	Beans	Orange		Ice cream	Cinnamon		Chips
Guinea pig		Flour (barley, fava, corn, wheat)	Beets	Papaya		Sugar (white, brown [*panela*])	Cumin		Coffee
Lamb		*Morocho*	Berry	Passion fruit			Black pepper		Tea
Milk		*Mote*	Cabbage	Peach			Cilantro		Rum
Pork		Oatmeal	Cauliflower	Peanuts			*Magi*		
Processed meat		Pasta	Cantaloupe	Pear			Oregano		
Rabbit		Popcorn	Carrot	Peas			*Perejil*		
Tripe		Quinoa	*Chocho*	Pineapple			*Sabora*		
Trout		Rice	Coconut	Pepper (hot, green)			Salt		
Tuna			Cucumber	Radish			*Tornil*		
Turkey			Greens	Raisins					
			Garlic	Turnip					
			Grapes	Tomato					
			Groundcherry	Tree tomato					
			Lemon	*Tuna*					
			Lentils	*Zambo*					
			Lettuce	*Zapote*					
				Zapallo					

(cattle, horses, etc.) owned (Pearson's $r = 0.80$, $P < 0.0001$), number of small animals (chickens, guinea pigs, etc.) owned ($r = 0.38$, $P < 0.007$), number of household goods ($r = 0.52$, $P < 0.001$)—and was in fact the criterion used by the community members to informally rank one another's wealth.

Statistical methods

The contribution of different food groups to the intake of energy and various nutrients was determined by calculating the percent contributed by each group (groups are listed in Table 2). To test the effect of sex, age, and land holdings on diet, we modelled the percentage of dietary energy contributed by each food group against sex, the age groups (<5 years, 5–9.9 years, 10–14.9 years, 15–19.9 years, 20–29.9 years, 30–39.9 years, 40–49.9 years, ≥50 years), and the household land holdings of <1 Ha, 1–2.4 Ha, 2.5–4.9 Ha, and ≥5 Ha (approximately one-quarter of the households are in each group). Therefore, in order to test for age and land holding effects on food intake, we used the following model:

$$\%E_g = \text{sex age land age*land sex*age sex*land house(land)}$$

where $\%E_g$ is the percentage of dietary energy from food group g, sex is a fixed effect (male or female), age is a fixed effect (eight age groups), land is a fixed effect (four land holding groups), age*land, age*sex, and sex*land represent the interactions of the main effects, and house(land) is the random effect of household, nested within land holdings. This last term accounts for differences between households. It is necessary to include this term because members of a given household will generally eat similar food and have a common value for land holdings and are thus not independent observations for testing the diet-land relationship. Including house(land), it is then valid to leave in multiple individuals per sex-age group within a household, maximizing the statistical power, and identifying sex, age, and land effects that exist independent of household differences. The means in each group are reported as least square means. This testing was doing using the PROC MIXED procedure of SAS 6.10 (SAS Institute Inc., Cary, NC).

The partitioning of variance in nutrient intake into intraindividual and interindividual variation was done by including in an

ANOVA the nutrient intake per day for all subjects with 2 or more days of data using the PROC ANOVA procedure of SAS. The interindividual variation is calculated by including subject in the model as a main effect; intraindividual variation is the residual (Beaton et al., 1979, 1983). This was done for three age groups (<10 years, 10–20 years, 20+ years); males and females were done separately. The age-group divisions represent the youngest, who do little house or farm work, the adolescents, who are in transition to becoming full working members of the household, and adults. For households with more than one individual in a sex-age group, one of the individuals was randomly chosen so that overrepresentation of one household does not bias the results for that sex-age group.

RESULTS

Description of diet in study community

Tubers (i.e., *melloco*, oca, potato) are a staple in the study population's diet; potatoes were eaten, on average, 2.7 times per day, but grains actually provided more of the total energy (see Table 3) largely in the form of white rice, white bread, barley flour (*machica* mixed with water- or milk-based coffee forms a pudding-like food, *chapo*), and pasta. Grains were the largest source of protein, potatoes the second largest. Animal foods, largely milk, provide only 7.7% of the energy but 17.5% of the protein in the diet.

Tubers are the leading source of iron, grains are the main source of zinc, and animal foods are the main source of calcium. Tubers provide more than 50% of the thiamin, niacin, and vitamin C and are also the most important sources of folate. Animal foods are the leading source of riboflavin and vitamin B-12. The vitamin B-12 in the sweets group is largely from powdered chocolate drink mix. However, the B-12 values come from Canadian food composition tables, and it is not unlikely that the fortification of Ecuadorian foods is very different. Thus, the relative contribution of sweets to vitamin B-12 intake is tentative.

The contribution of protein, fat, and carbohydrates to the diet of the study population is shown in Table 4. As would be expected on a tuber and grain based diet, approximately

TABLE 3. Percent contribution of various food groups to macronutrient, mineral, and vitamin intake in study community

		Macronutrients				Minerals			Vitamins						
Food group	Water	Energy	Protein	Fat	Carbohydrates	Calcium	Iron	Zinc	A	Thiamin	Riboflavin	Niacin	B-12	C	Folate
Water	56.7	—[1]	—	—	—	2.0	3.3	—	—	—	—	—	—	—	—
Grains	2.5	34.2	41.4	12.5	36.5	17.5	31.9	36.0	3.3	22.3	18.6	26.2	0.0	3.8	28.3
Tubers	25.3	24.7	29.4	2.9	26.9	17.8	43.4	33.2	1.4	61.4	20.1	58.0	0.0	62.6	41.1
Fruit/vegetable	5.2	4.0	5.8	2.6	4.3	10.3	6.3	5.9	74.1	8.0	10.0	4.7	0.0	23.9	19.8
Animal	8.4	7.7	17.5	26.7	2.4	36.1	5.1	19.8	14.6	4.1	38.2	4.8	93.1	1.7	8.5
Oils	0.0	5.6	0.0	45.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Sweets	1.4	21.0	1.9	4.7	27.0	8.2	6.4	2.5	0.9	0.8	7.1	1.0	6.9	0.4	0.3
Spice	0.3	0.2	0.5	0.2	0.2	3.3	1.4	—	4.4	0.8	3.2	0.5	—	7.3	—

[1] Data unavailable. Assumed to be 0.0.

TABLE 4. The mean, standard deviation, and range of percent contribution to dietary energy of protein, fat, and carbohydrate in children (<10 years), adolescents (10–20 years), adults (>20 years), and pregnant or lactating females[1]

	Age group and sample size[2]			
	<10 (n = 207)	10–20 (n = 152)	>20 (n = 305)	P/L[3] (n = 32)
% protein	9 ± 2	10 ± 2	10 ± 2	10 ± 2
	5–20	5–16	6–17	7–15
% fat	12 ± 4	13 ± 5	14 ± 6	13 ± 3
	5–30	3–28	3–45	7–22
% carbo-hydrate	82 ± 6	79 ± 7	77 ± 7	79 ± 4
	67–97	61–91	41–91	69–85

[1] The mean ± SD is given, followed by a range indicating the lowest single day value and the highest single day value. Column totals >100% due to rounding errors and to the inherent inaccuracies of the weight-to-calorie conversion factors (for protein, fat, and carbohydrate equals 16.7, 37.6, and 16.7 kJ/g, respectively).
[2] All days of dietary data included in analysis (total n = 696).
[3] P/L, pregnant or lactating.

80% of the dietary energy is in the form of carbohydrates, and protein and fat each make up less than 15% of the diet.

Variation in diet between sexes and across ages and socioeconomic status

The variation in the diet within the community can be examined by differences in the percentages of energy supplied by various food groups, using the model described in Materials and Methods. There were no instances of sex main effects or interactions, so the analyses were repeated excluding sex. The results are summarized in Table 5. The least square means for each group are shown only if the *P* value for the main effect is <0.05.

The differences between SES groups are most noticeable between those households with greater than 5 Ha and those households with less. The households with ≥5 Ha eat more animal foods (11.4% compared to ~7%), less tubers (18% vs. 25–30%), and more grains (40% vs. 28% for <1 Ha and 33% for 2.5–4.9 Ha).

There are a number of age differences in sources of dietary energy. Adults consume relatively more tubers (particularly in households with <1 Ha) and relatively fewer sweets (particularly in households with <5 Ha). The intake of sweets is largely refined sugar or *panela* (unrefined sugar), which were used liberally in their coffee (e.g., 25–75 g per 300 ml cup). Oil intake is slightly lower in the children (<10 years).

TABLE 5. Percent contribution of various food groups to dietary energy intake by age group and household land holdings (land)[1]

		P values for main effects and interaction			Least squares mean % contribution by land (Ha) (n in households)				Least squares mean % contribution by age group (years) (n in age group)							
	Mean % contribution	Land	Age	Age* land	<1 (16)	1–2.4 (9)	2.5–4.9 (12)	≥5 (13)	<5 (30)	5–9.9 (37)	10–14.9 (30)	15–19.9 (23)	20–29.9 (41)	30–39.9 (19)	40–49.9 (22)	≥50 (19)
Grains	34	0.02	0.93	0.46	33^{ab}	37^{ac}	28^{b}	40^{c}								
Tubers	25	0.02	0.00	0.00	25^{a}	26^{a}	30^{a}	18^{b}	21^{a}	23^{b}	24^{b}	28^{c}	23^{b}	28^{c}	28^{c}	28^{c}
Sweets	21	0.20	0.00	0.00					26^{a}	24^{b}	21^{c}	17^{d}	19^{e}	18^{de}	16^{d}	18^{de}
Animal	7.7	0.03	0.69	0.20	6.7^{a}	6.6^{a}	7.4^{a}	11.4^{b}								
Oils	5.6	0.17	0.00	0.00					4.7^{a}	5.4^{ac}	5.6^{bc}	6.2^{bc}	6.4^{b}	6.4^{b}	5.8^{ab}	5.8^{ab}
Fruit/vegetable	4.0	0.32	0.33	0.03												

[1] Within a row, values with different superscripts have unequal least square means (comparison-wise error rate of *P* < 0.05). The least square means for each group are shown only if the *P* value for the main effect is <0.05. Interactions (*P* < 0.05): tubers: age effect is greatest for land <1, intermediate for land = 1–4.9, not present for land >5; sweets: age effect is greatest for land <5, small, but present for land >5; oils: age effect is greatest for land ≥2.5, small, but present for land <2.5.

TABLE 6. Intake of energy and 12 nutrients by sex and age group[1]

	Male			Female		
	<10 years	10–20 years	>20 years	<10 years	10–20 years	>20 years
n(m)[2]	24 (3.3)	15 (2.8)	39 (3.5)	17 (2.8)	13 (3.6)	41 (3.7)
Energy (kJ) $\bar{x}$	5,402	8,967	10,924	5,498	8,475	9,952
SD_{intra}	1,963	4,369	3,496	1,658	2,494	3,117
SD_{inter}	1,699	0.0	2,019	1,070	1,536	1,541
Protein (g) $\bar{x}$	31.3	57.2	68.5	32.7	50.7	62.8
SD_{intra}	14.6	37.8	29.3	11.2	15.7	26.5
SD_{inter}	11.2	0.0	14.5	9.7	7.8	10.6
Fat (g) $\bar{x}$	17.9	31.0	39.2	18.3	28.3	37.1
SD_{intra}	10.4	22.2	19.9	8.9	13.3	18.7
SD_{inter}	6.3	0.0	10.9	5.7	1.0	7.7
Water (ml) $\bar{x}$	1,250	2,084	2,609	1,270	2,047	2,414
SD_{intra}	276	635	655	279	374	630
SD_{inter}	393	368	371	290	403	402
Minerals						
Calcium (mg) $\bar{x}$	234	422	470	241	404	417
SD_{intra}	144	334	240	102	175	230
SD_{inter}	62	0	114	82	109	66
Iron (mg) $\bar{x}$	14.3	24.8	31.5	14.5	25.6	28.3
SD_{intra}	5.2	10.7	11.9	4.3	8.0	10.4
SD_{inter}	3.9	1.3	2.9	3.8	4.0	3.5
Zinc (mg) $\bar{x}$	3.9	6.9	8.8	4.2	6.3	8.2
SD_{intra}	2.8	4.0	4.8	2.3	2.3	4.9
SD_{inter}	1.2	0.0	1.4	0.0	1.1	0.0
Vitamins						
Vit A (RE) $\bar{x}$	334	638	620	314	596	619
SD_{intra}	242	836	472	186	323	507
SD_{inter}	164	0.0	231	169	263	218
Thiamin (mg) $\bar{x}$	0.93	1.55	2.10	0.91	1.65	1.87
SD_{intra}	0.42	0.88	0.88	0.36	0.56	0.78
SD_{inter}	0.28	0.00	0.19	0.18	0.20	0.24
Riboflavin (mg) $\bar{x}$	0.49	1.03	1.18	0.51	0.89	1.01
SD_{intra}	0.32	1.12	1.10	0.29	0.55	0.81
SD_{inter}	0.10	0.00	0.25	0.16	0.25	0.00
Niacin (NE) $\bar{x}$	15.1	24.6	34.2	15.4	27.2	31.0
SD_{intra}	5.8	11.2	14.8	5.1	9.8	12.8
SD_{inter}	4.0	2.8	4.1	3.7	4.7	3.9
Vitamin B-12 (μg) $\bar{x}$	0.79	1.15	1.68	0.89	1.01	1.78
SD_{intra}	1.15	0.96	1.77	1.16	0.75	2.24
SD_{inter}	0.00	0.60	0.68	0.60	0.33	0.35
Vitamin C (mg) $\bar{x}$	71.6	118.5	166.2	67.9	125.8	150.5
SD_{intra}	36	49.4	74.8	28.8	49.1	70.1
SD_{inter}	15.9	26.9	0.0	16.7	19.4	18.8
Folate (μg) $\bar{x}$	91.2	181.7	204.2	96.2	145.3	184.1
SD_{intra}	49.7	172.2	121.1	64.0	58.3	112.8
SD_{inter}	27.6	0.0	0.0	11.8	12.9	0.0

[1] $\bar{x}$, mean; SD_{inter}, interindividual standard deviation; SD_{intra}, pooled intraindividual standard deviation. When there was more than one individual per sex-age group from a given house, the data from only one individual was used (randomly selected).
[2] Sample size (mean number of days of dietary data per subject).

Inter- and intraindividual sources of variation in the intake of energy and nutrients

The mean intake and the inter- and intraindividual standard deviation in nutrient intake are shown for energy, water, and 12 nutrients in Table 6. An assessment of the adequacy of these intakes appears elsewhere (Berti et al., in press a,b). Briefly, the intakes of dietary energy, protein, iron, thiamin, niacin, and vitamin C are generally adequate; the intakes of protein, calcium, zinc, vitamins A and B-12, riboflavin, and folate are generally inadequate. Higher rates of inadequacy tend to be found in children and in the poorer families.

DISCUSSION

Description of diet in study community

Consistent with other studies of the diet of rural Andean people (e.g., de Meer, 1993; Leonard, 1987; Leonard et al., 1993), the diet in this community can be characterized as tuber-based. However, the importance of

potatoes as a source of dietary energy in other Andean communities ranges from much lower (9% of energy in Nuñoa, Peru, 1967 [Gursky, 1969]) to higher (41% of energy in Nuñoa, 1985 [Leonard, 1987]). Tubers are the most important dietary source of two minerals and four vitamins and the second most important source of dietary energy, protein, carbohydrates, zinc, and riboflavin.

Grains are the leading source of energy, protein, carbohydrates, and zinc and are an important source of two other minerals and four other vitamins. Animal foods make up a small part of the diet but still contribute substantial amounts of calcium, zinc, and three vitamins. Fruits and vegetables are a relatively small part of the diet but provide most of the vitamin A and are an important source of vitamin C and folate. Sweets provide a large amount of energy but few nutrients.

Variation in diet between sexes and across ages and socioeconomic status

The lack of a sex effect on dietary intake supports our recent work that, unlike the case in many parts of the developing world, Andean households tend to avoid sex-based bias in food distribution (Berti et al., 1995, in press a; Leonard, 1991; Hamilton et al., 1996).

The relationship between increased wealth and increased consumption of animal foods is observed throughout the world (Kazuo, 1995). In this community, much of the animal food is milk (65% of animal food by energy). Milk can be sold by the farmers (≈US$0.25/litre) and is often an important source of income. The wealthier households have more cows producing more milk, and they can afford to drink milk, whereas the poorer households, if they have producing cows, often choose to sell their milk rather than drink it, accounting for the higher consumption of animal foods by the larger landholders. The low intake levels of micronutrient-rich animal foods by the poorer families leads to the poorer individuals having an increased risk of inadequate intakes of some of those nutrients supplied by animal foods and not supplied in sufficient amounts by tubers or grains (zinc, calcium, vitamin B-12) (Berti et al., in press b).

The replacement of home-produced staples (tubers, barley) with store-bought grains (rice, wheat) in the wealthier households has been observed elsewhere in highland Ecuador (Weismantel, 1988) and Peru (Leonard, 1987) and is likely an indication of the wealthier families using their increased disposable income to purchase food they cannot produce themselves.

The most noticeable age-based difference in diet is the high sweets/low tubers in the children gradually changing to low sweets/high tubers in the adults. There are at least two contributing reasons for this difference. First, children do prefer sweeter flavors than adults (Drewnowski and Popkin, 1997), and so they do put more sugar in their coffee and drink more sweetened drinks (*bolos*) available in the community store. Second, because of the high satiating effect of potatoes (Holt et al., 1995) and the smaller stomach volume of children, they may not be physically able to consume the same relative amount of tubers. Replacing tubers with sweets as an energy source is actually a reasonable response by the children, but the low micronutrient content of sweets leads to increased risk of dietary inadequacy.

Inter- and intraindividual sources of variation in the intake of energy and nutrients

The attribution of interindividual variation in health outcome to interindividual variation in diet is difficult; for example, correlations between intakes of single nutrients and health outcome measures, such as anthropometrics, are typically low in nutritional surveys (e.g., the CRSP study [Allen et al., 1991]). This is at least in part due to the many factors other than single nutrients that contribute to an individual's health. However, even when diet-health relationships exist, true interindividual dietary differences are often hidden by the intraindividual noise. The level of intraindividual variation (SD_{intra}) relative to interindividual variation (SD_{inter}) can be expressed as a variance ratio (VR), which equals $SD_{intra} \div SD_{inter}$. The VRs for this study are not shown but can be easily calculated from Table 6.

They range from 0.7 (water, males <10 years) to infinity (in the 16 cases where the SD_{inter} is 0). Only for water are there VRs less than 1. Both zinc and folate have infinite VRs three times. The statistical observance of health-nutrient relationships is facilitated by having a low VR (e.g., <1), but of course we must work with the variation present in the sample population. In this community, the VR is too high for most nutrients to detect moderate (e.g., $r < 0.5$) nutrient-health correlations. For example, with a sample size of 20 subjects and an α value of 0.05, the critical correlation coefficient is $r = 0.433$ (Snedecor and Cochran, 1989). If there are 3 days of data per subject and the $VR = 3.0$, the attenuation factor will be 0.71 ($= 1/[\sqrt{(1 + VR/n)}]$, from Liu et al. [1978]). This means that only if the true correlation is $r \geq 0.61$ (i.e., 0.433/0.71) will the observed correlation be considered significant, and such strong correlations between single nutrient intake and any health outcome measure must be exceedingly rare. And in the cases where the SD_{inter} is 0 (and the VR infinite), it will be impossible to observe health-diet relationships.

Having a high VR for most nutrients may be typical for populations in the developing world, whereas in developed countries the VRs are often close to 1. Using energy and protein in adult females for example, the VRs in this study are 2.0 and 2.5, in Mexico 1.2 and 2.7 (Calloway et al., 1988), and in Bangladesh 1.9 and 9 (Torres et al., 1990). By contrast, in Toronto the VRs for energy and protein were 1.2 and 1.2 (Beaton et al., 1979), and in Cambridge they were 1.2 and 1.4 (Nelson et al., 1989). The between-subject homogeneity of the diet in the Ecuadorian, Mexican, and Bangladesh communities, and perhaps in most developing world communities, is likely due to a limited number of food choices (whereas thousands of food choices are available to residents of Toronto and Cambridge, only 105 foods, including spices, were reported consumed in the study community) and the usual pattern of three meals per day (vs. developed countries, where one to three meals and one to four or more snacks are common [Cross et al., 1994]). The high SD_{intra} of the Ecuadoreans, Mexicans, and Bangladeshi (and, again, perhaps throughout the developing world) may be a function of low food security and relatively high day-to-day fluctuations in food supply, but a detailed analysis of this phenomenon (Beaton and Lein, 1988) could not identify what was driving the high day-to-day variance. If a high SD_{intra} and low SD_{inter} are typical of most developing countries, it would, at least in part, explain the difficulty of observing relationships between intake of single nutrients and health outcome measures (Allen, 1994; Allen et al., 1992).

TABLE 7. The 95% confidence interval for percentage deviation of individual energy and protein intake in adult men in Ecuador (this study) and Toronto (Beaton et al., 1979)

Obs/ person[1]	Energy		Protein	
	Toronto	Ecuador	Toronto	Ecuador
1	51	64	71	87
2	36	45	50	61
3	29	37	41	50
4	26	32	36	43
5	23	29	32	39

[1] Observations (i.e., days of data) per person.

Following the partitioning of variance, it is also possible to estimate the magnitude of the 95% confidence interval for percent deviation of individuals' ($CI_{individual}$) and groups' (CI_{group}) nutrient intake level, using the formulas $CI_{individual} = (2/\sqrt{n}) \cdot (SD_{intra} \div \overline{X})$ and $CI_{group} = (2 \cdot ((SD_{inter} \div \overline{X})^2/g + (SD_{intra}/\overline{X})^2/gn)^{1/2}$, where $\overline{X}$ = mean intake, n = observations/person, and g = group size (Beaton et al., 1979). The $CI_{individual}$ and CI_{group} for this study and the Toronto study are shown in Tables 7 and 8. As one may have presumed from the relative magnitudes of SD_{inter} (Ecuador $<$ Toronto) and SD_{intra} (Ecuador $>$ Toronto), the confidence intervals of the Toronto data are somewhat smaller than the Ecuador data for estimation of individual intakes but somewhat larger than the Ecuador data for estimation of the group mean intake.

CONCLUSIONS

With these data, we demonstrate the importance of tubers (mostly potatoes) as not only a dietary energy source but also as a source of most nutrients in this rural Andean community. The poverty of many people

TABLE 8. The 95% confidence interval for percentage deviation in group mean energy intake in adult men in Ecuador (this study) and Toronto (Beaton et al., 1979)

Group size[1]	Obs/ person[2]	Toronto	Ecuador
5	1	32.0	32.5
5	2	27.6	25.5
5	3	25.9	22.6
10	1	22.6	23.0
10	2	19.5	18.0
10	3	18.3	16.0
20	1	16.0	16.3
20	2	13.8	12.7
20	3	13.0	11.3
50	1	10.1	10.3
50	2	8.7	8.1
50	3	8.2	7.2
100	1	7.2	7.3
100	2	6.2	5.7
100	3	5.8	5.1
200	1	5.1	5.1
200	2	4.4	4.0
200	3	4.1	3.6

[1] Number of individuals for whom there is data.
[2] Observations (i.e., days of data) per person.

in this community prevents access to sufficient nutrient-dense foods (e.g., meat, milk), which will lead to inadequate intakes of those nutrients not sufficiently supplied by tubers or grains (e.g., vitamin B-12, zinc). This appears to be a particular problem for children. Since the nutrient density (nutrients/gram wet weight) of tubers is low to moderate for most vitamins and minerals and because of the high satiating effect of potatoes, children may be unable to consume sufficient tubers to meet their micronutrient requirements. As such, children may be at high risk for nutrient deficiencies, especially among poorer families with limited access to meat and milk (Berti et al., in press a).

However, our ability to document the health effects of nutrient deficiencies in third-world communities may be quite low. High VRs have now been observed in a number of developing countries, including Mexico (Calloway et al., 1988), Bangladesh (Torres et al., 1990), and Ecuador (this study), and may well be observed throughout the developing world. This must be considered when planning nutrition surveys and anthropological studies in developing countries; there are two issues to consider. First, the low interindividual variation indicates that relatively few subjects are required to estimate the nutrient intake of the population, facilitating group comparisons. Second, the high intraindividual variation indicates that several observations per subject are required to characterize the nutrient intake of individuals, hindering attempts at relating nutrient intake to other measures. This implies that attempts to discern relationships between dietary and health measures will likely be most successful when aggregate, group-level analytical approaches are used rather than correlation/regression analysis. An increased appreciation of the magnitude of the variation in the diets in developing countries will lead to better study designs and realistic expectations for the explanatory and descriptive power of the dietary data.

ACKNOWLEDGMENTS

We thank the residents of the study community for their willing participation in this study. Wilma Berti provided expert assistance in the field. The SAS program used to do the partitioning of variance was kindly supplied by Professor G.H. Beaton of the University of Toronto. Dr. R.S. Gibson of the University of Otago made helpful comments on an earlier version of this paper. P.R.B. was supported by a Natural Science and Engineering Research Council PGS B postgraduate scholarship, an Ontario Graduate Scholarship and an International Development Research Centre of Canada Young Canadian Researchers Award.

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